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Implementation Of Tabu Search Algorithm to Solve the Capacitated Vehicle Routing Problem (CVRP) In Medicine Distribution Route

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ABSTRACT

One of the optimization issues is the Vehicle Routing Problem (VRP). VRP can consider distance alone or take into account other factors such as traffic congestion, road quality, and obstacles to serve multiple agents according to their requests. The Capacitated Vehicle Routing Problem (CVRP), which adds vehicle capacity constraints, is a variant of VRP. This paper aims to explain the construction of a CVRP model for the problem of drug distribution routes from a depot to several pharmacies. An approach called Tabu Search is proposed to overcome these optimization challenges. The main objective of this method is to stop the iterative search for solutions that have already been sought. In this study, the travel route for the example of a PT. XYZ Salesman was constructed using the Tabu Search approach. The results obtained a minimum travel distance of 27.9 km and a minimum travel time of 35.2 minutes, with a maximum delivery quantity of 63 boxes.

Keywords: *Tabu search algorithm, Capacitated vehicle routing problem, Medicine distribution route.*

ABSTRAK

Salah satu permasalahan optimasi rute distribusi adalah Vehicle Routing Problem (VRP). VRP mempertimbangkan dari jarak, kemacetan lalu lintas, kualitas jalan, dan hambatan untuk melayani beberapa agen sesuai permintaan mereka. Capacitated Vehicle Routing Problem (CVRP), merupakan varian dari VRP yang menambahkan kendala kapasitas kendaraan didalamnya. Makalah ini bertujuan untuk menjelaskan konstruksi model CVRP pada permasalahan rute distribusi obat dari depot ke beberapa apotek. Pendekatan yang diusulkan untuk mengatasi tantangan optimasi ini adalah Tabu Search. Tujuan utama dari metode ini adalah menghentikan pencarian berulang untuk solusi-solusi yang telah dicari. Dalam penelitian ini, rute perjalanan untuk contoh Salesman PT. XYZ dibangun menggunakan pendekatan Tabu Search. Hasil yang diperoleh adalah jarak tempuh minimum 27,9 km dan waktu tempuh minimum 35,2 menit, dengan kuantitas pengiriman maksimum 63 kotak.

Kata kunci: Tabu search algorithm, Capacitated vehicle routing problem, Rute distribusi obat.

I. INTRODUCTION

The problem of determining the vehicle route used to distribute goods to several distributors from a depot to minimize the total travel costs that meet the given constraints is included in the problem called the Traveling Salesman Problem (TSP) [1][2][3]. The fundamental component of TSP is that a salesperson must visit several agents in one trip, visiting each agent only once before returning to the depot [4][5]. The fundamental idea of the Tabu Search approach is to steer each step toward producing the best possible outcome while avoiding being mired in the first answer that is discovered at this stage [6][7][8]. To avoid duplication, this approach seeks to identify the identical answer in a single iteration, which will be applied again in the subsequent iteration [9]. The TSP problem can be solved using the Tabu Search approach by navigating the two-point exchange [10].

The Capacitated Vehicle Routing Problem (CVRP) is a variant of the Vehicle Routing Problem (VRP) that is subject to vehicle capacity limits [11]. The distribution of medications to pharmacies that subscribe is one of the issues that arise while using CVRP [12]. The CVRP issue is an optimization problem that determines the least expensive routes for several homogeneous vehicles with a given capacity, serving multiple distributors, where the number of requests is known ahead of the distribution process. Distribution in each vehicle is limited to one round trip, which is from the depot to each pharmacy and back again [13][14]. For a distribution route planning system to become more effective and efficient and enabling the business to meet product demand faster, boosting customer happiness and trust [15].

To find the best route with the least amount of travel time and distance and to maximize the number of items that can be transported in a single trip, this study will look at the stages that the tabu search method takes to solve the TSP problem. The salesmen's journey time and distance to pharmacies are symmetric data in the TSP problem for determining the best routes utilizing information from PT. XYZ. The salesman's travel data is then modeled in graph form. The Salesman's journey graph used is a weighted and undirected complete graph.

Various algorithms have been proposed to address the Capacitated Vehicle Routing Problem (CVRP), ranging from classical heuristics such as the Nearest Neighbor to modern metaheuristics like Tabu Search (TS), Ant Colony Optimization, and Hybrid Quantum-TS. For instance, Utama et al. (2019) found that Tabu Search was able to reduce travel distance by up to 10% compared to the Nearest Neighbor approach in a study focused on daily goods distribution [16]. In the research, Braysy and Gendreau (2002) developed a TS-based algorithm for CVRP with time windows, effectively incorporating customer service schedules [17]. Latest research, hybrid Quantum-Classical Tabu Search approaches have demonstrated improvements in solution quality for mid-scale CVRP benchmarks, although their practical applicability remains under ongoing evaluation [18].

Solving the TSP using the Tabu Search method begins with the TSP problem, which is modeled as a complete graph with specified travel distances and times [19][20]. Finding the initial path and designating it as the optimal starting route is the next stage. The initial route is saved to the Tabu List. Next, do the first iteration by evaluating the initial route using neighborhood search, and get the latest route in this first iteration. The Tabu List contains the new route that was discovered during the first iteration. In the second iteration, a new route is found using this approach, similar to the first iteration, where the route is evaluated using neighborhood search, resulting in a new route being obtained in the second iteration. Do this repeatedly until the specified maximum iteration is reached. The route is first compared to the Tabu List's contents at each iteration before being assessed. It won't be assessed once more in that iteration if it already exists. The Tabu List contains the optimal routes from each iteration. The route with the minimum travel distance and travel time of all these routes is the optimal route for the TSP problem.

A graph is described as two sets (V, E) represented by G (V, E), where V is a non-empty finite set with vertices or nodes as its constituents, and E is a collection of edges or arcs joining two nodes [21][22]. Graphs can be grouped into several types depending on the grouping point of view, the number of vertices, the orientation of the edges, and the existence or absence of numerous edges can all be used to categorize graphs. Generally speaking, graphs fall into two categories: simple graphs and non-simple graphs, depending on whether or not they have loops and double edges. A graph is considered non-simple if it contains loops and double edges, whereas a simple graph does not have either of these features.

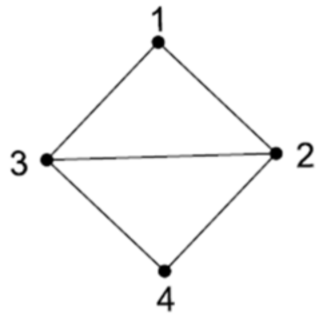

Figure 1. Simple Graph

II. RESEARCH METHOD

Tabu Search is a heuristic method that is generally used to find solutions that are close to optimal to a problem by making moves [23]. The movement under consideration is searching through and selecting various solutions. Tabu Search improves local search performance by exploiting the use of memory structures. The tabu list, a basic memory structure, holds optimal

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solutions discovered during earlier cycles. The Tabu List is also used to guide the search process to explore solutions that have never been visited so that repetition does not occur.

Tabu List uses four principles, namely:

1. Recency-based memory, namely, memory that maintains the best structure of the initial solution found during the search processes at each iteration. If, during an iteration, a better solution is found, this solution will be maintained until a new, better solution is found.
2. Frequency provides a type of information that is a collection of information that has been recorded by frequency-based memory. So, frequency and recency can complement each other to form permanent information that is useful for evaluating movements that occur.
3. Quality is the ability to distinguish the best solutions visited during the search or iteration.
4. Influence considers the effects that occur from selecting the chosen solution during the search.

Tabu Search has four main parameters that must be determined, namely:

1. Local search procedure.
2. Neighbourhood structure, namely, a neighbourhood that is built to identify neighbouring solutions that can be achieved from the current solution.
3. Taboo conditions are a prohibition on using previously discovered solutions.

Termination criteria, several user-defined iterations, a predetermined amount of time, or multiple consecutive iterations without raising the value of the optimal objective function are examples of criteria that can be used to halt the Tabu Search process.

III. III.RESULTS AND DISCUSSION

A Salesman PT. XYZ is tasked with checking the availability of medicines at each pharmacy. The salesman who will travel from PT. XYZ (0) to Asri Indah Pharmacy (1), Sehat Waras Pharmacy (2), Hijau Daun Pharmacy (3), Medica Pharmacy (4), Serayu Pharmacy (5), and Cermen Pharmacy (6), then the Salesman must return to PT. XYZ. To save on travel time and distance, these pharmacies must be visited exactly once. A map of the pharmacies visited can be seen in Figure 2, and in Table 1, the pharmacies to be visited are listed along with the distance traveled in kilometers and travel time in minutes. Figure 2 is an illustration of the journey of a PT Salesman. XYZ is represented in graph form. The vertices in the graph represent the posts the Salesman will go to, the edges in the graph represent the path the Salesman takes from one pharmacy to another, and then the weights in the graph represent the distance traveled or travel time spent by the Salesman.

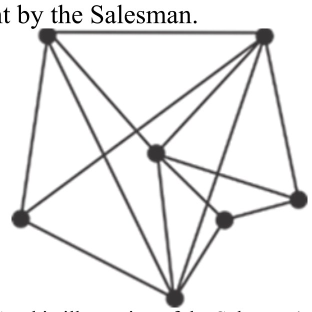

Figure 2. Graphic illustration of the Salesman's Journey PT. XYZ

Figure 2 shows that the pharmacies to be visited are connected. Table 1 shows a Salesman PT's overall travel distance and travel time. XYZ as in Figure 1. Travel distance (d) in kilometers and travel time (t) in minutes, the assumptions used are as follows:

1. The company can fulfil every agent's order.
2. The number of requests for each pharmacy is fixed.
3. The vehicle used to carry a capacity of ≤300 boxes is a motorbike, for a capacity of 300 boxes – 1000 boxes, a three-wheeled motorbike/tosa, for a capacity of 1000 boxes – 10,000 boxes is a box car.
4. The average speed used by each vehicle is 40 km/hour, and there are no traffic jams, the road conditions are not damaged, and the vehicles are in normal condition.
5. Delivery times at each pharmacy are between 08.00 – 18.00 WIB.
6. The resulting pick-up time includes the length of service at each pharmacy, which is around 5 minutes.

Table 1. Overall Distance and Time

Pharmacy	PT. XYZ (0)		Asri Indah Pharmacy (1)		Sehat Waras Pharmacy (2)		Hijau Daun Pharmacy (3)		Medica Pharmacy (4)		Serayu Pharmacy (5)		Cermen Pharmacy (6)	
	d	t	d	t	d	t	d	t	d	t	d	t	d	t
PT. XYZ (0)	0	0	4,7	5,6	6,2	6,8	8,9	13,2	6,6	9,2	5,8	6,2	3,2	4,5
Asri Indah Pharmacy (1)	4,7	5,6	0	0	4,8	3,2	4,7	7,1	4,7	7,1	9,2	13,8	4,1	3
Sehat Waras Pharmacy (2)	6,6	6,7	4,8	3,2	0	0	12,3	18,5	9,6	14,4	12	18	6,5	7,2
Hijau Daun Pharmacy	8,9	13,2	4,7	7,1	6,3	7,5	0	0	7	8,5	6,6	6,7	5,8	8,2

(3)														
Medica Pharmacy (4)	4,8	3,2	4,7	7,1	9,6	14,4	8,5	6,6	0	0	4,8	3,2	8,2	9,8
Serayu Pharmacy (5)	5,8	8,2	9,2	13,8	12	18	6,6	6,7	4,8	3,2	0	0	4,4	7,2
Cermen Pharma chy (6)	3,2	4,5	4,1	3	6,5	7,2	5,8	8,2	8,2	9,8	4,4	7,2	0	0

Table 2. Customer Demand Data per Box

Pharmacy Name	April			
	Week-1	Week-2	Week-3	Week-4
Asri Indah pharmacy (1)	35	56	70	70
Sehat Waras pharmacy (2)	77	63	85	82
Hijau Daun pharmacy (3)	44	62	62	70
Medica pharmacy (4)	30	45	45	60
Serayu pharmacy (5)	64	70	75	86
Cermen pharmacy (6)	48	30	54	68

The steps taken are to optimize travel distance, travel time, and the capacity of PT salesmen. the XYZ. The first step is to identify the starting route and decide whether it is the best solution for the first stage. Capacity is determined from each pharmacy's orders each week, starting from week 1. The initial route is determined using the nearest neighbors, and the initial route is obtained as 0-6-1-5-2-4-3.

Distance traveled (d)	:	3,2 + 4,7 + 5,8 + 6,2 + 6,6 + 8,9 = 35,4 km.
Travel time (t)	:	4,5 + 5,6 + 6,2 + 6,8 + 9,2 + 13,2 = 45,5 minute.
Capacity	:	0 + 48 + 35 + 64 + 77 + 30 + 44 = 298 box.

At iteration 0, this first route is added to the tabu list, along with the initial solution for travel distance and journey time. Finding a different approach and deciding on the next iteration are the steps that follow. Neighborhood search, which employs combination rules, yields an alternative solution. Completion of TSP to obtain optimal travel distance and travel time is achieved by swapping 2 points or swapping the positions of 2 distances/times sequentially. Since each post may only be visited exactly once, the number of combinations of these problems with a combination of trips made by determining the optimal route is C62 = 12. Hence, 12 travel paths total are created as alternate routes during each iteration. The process ends if the requirements for termination are satisfied. The research employed halting conditions that were applied once all iterations were completed. The number of iterations carried out was 60. The following is the process of finding alternative paths for these iterations:

Iteration 1:

Search for alternative routes for distance and travel time.

Initial path:

0-6-1-5-2-4-3-0 with a 35.4 km journey distance, 45.5 minutes transit duration, and 298 box capacity.

Table 3. Search for alternative routes for travel distance and travel time Iteration 1

No	Changing	Travelled Route	Distance (km)	Time (minute)	Total capacity (box)
1	Swap 6,1	0-1-6-5-2-4-3-0	45,2	55,5	298
2	Swap 6,5	0-5-1-6-2-4-3-0	31,4	42,7	298
3	Swap 6,2	0-2-1-5-6-4-3-0	33,1	44,8	298
4	Swap 6,4	0-4-1-5-6-2-3-0	35,7	45,9	298
5	Swap 6,3	0-3-1-5-2-4-6-0	35,4	45,5	298
6	Swap 1,5	0-6-1-5-2-4-3-0	32,6	43,7	298
7	Swap 1,2	0-6-2-5-1-4-3-0	36,2	49,8	298
8	Swap 1,4	0-6-4-5-2-1-3-0	38,4	51,2	298
9	Swap 1,3	0-6-3-5-2-1-4-0	37,3	50	298
10	Swap 5,2	0-6-1-2-5-4-3-0	33,8	42,5	298
11	Swap 5,4	0-6-1-4-2-5-3-0	40,5	48,9	298
12	Swap 5,3	0-6-1-3-2-5-4-0	41,7	45,5	298
13	Swap 2,4	0-6-1-5-3-2-4-0	35	39,5	298
14	Swap 2,3	0-6-1-5-2-4-3-0	40,2	53,2	298
15	Swap 4,3	0-6-1-5-2-3-4-0	42	54,6	298

In this 1st iteration, the best value was 31.4 km for travel distance, 42.7 minutes for travel time, and a capacity of 298 boxes, namely on the 2nd Line. Next, do the 2nd iteration. Use the same calculations as the first iteration for computations from the second iteration to the second iteration based on the salesman's path.

The minimum travel distance and journey time were found for each iteration once 60 calculations were completed. Table 4's Tabu List contains the minimum travel distance and journey duration that were determined after every iteration. In Table 4, the iteration outcomes of each evaluation are explained in the first column, and the second column represents the optimal path from each evaluation, where the trip route with the least amount of time and distance traveled is the best way.

Table 4. Tabu List with minimum travel distance and travel time for each iteration

Iteration	Path	Travelled route	Distance (km)	Time (minute)	Capacity Week 1	Week 2	Week 3	Week 4
1	0	0-1-6-5-2-4-3-0	45,2	55,5	298	298	226	391
2	6	0-5-1-6-2-4-3-0	31,4	42,7	298	298	226	391
3	5	0-2-1-5-6-4-3-0	33,1	44,8	298	298	226	391
4	4	0-4-1-5-6-2-3-0	35,7	45,9	298	298	226	391
5	3	0-3-1-5-2-4-6-0	35,4	45,5	298	298	226	391
6	1	0-6-1-5-2-4-3-0	32,6	43,7	298	298	226	391
7	2	0-6-2-5-1-4-3-0	36,2	49,8	298	298	226	391
8	14	0-6-4-5-2-1-3-0	38,4	51,2	298	298	226	391
9	13	0-6-3-5-2-1-4-0	37,3	50	298	298	226	391
10	8	0-6-1-2-5-4-3-0	33,8	42,5	298	298	226	391
11	7	0-6-1-4-2-5-3-0	40,5	48,9	298	298	226	391
12	9	0-6-1-3-2-5-4-0	41,7	45,5	298	298	226	391
13	10	0-6-1-5-3-2-4-0	35,0	39,5	298	298	226	391
14	12	0-6-1-5-2-4-3-0	40,2	53,2	298	298	226	391
15	11	0-6-1-5-2-3-4-0	42,0	54,6	298	298	226	391
16	15	0-2-1-6-5-4-3-0	40,2	45,4	298	298	226	391
17	16	0-4-1-6-5-2-3-0	45,2	49,6	298	298	226	391
18	17	0-3-1-6-5-2-4-0	42,0	49,8	298	298	226	391
19	18	0-5-1-2-6-4-3-0	33,8	39,8	298	298	226	391
20	19	0-5-1-4-2-6-3-0	40,2	48,9	298	298	226	391
21	20	0-5-1-3-2-6-4-0	41,7	49,8	298	298	226	391
22	21	0-5-1-6-3-2-4-0	35,4	45,5	298	298	226	391
23	22	0-5-1-6-2-4-3-0	31,4	42,7	298	298	226	391
24	23	0-5-1-6-2-4-3-0	38,4	51,2	298	298	226	391
25	24	0-6-2-1-5-4-3-0	36,2	49,8	298	298	226	391
26	25	0-6-1-5-2-4-3-0	32,6	43,7	298	298	226	391
27	26	0-6-1-5-2-4-3-0	32,6	43,7	298	298	226	391
28	**27**	**0-6-1-5-2-4-3-0**	**32,6**	**43,7**	**298**	**298**	**226**	**391**
29	28	0-6-1-5-2-4-3-0	32,6	43,7	298	298	226	391
30	29	0-6-1-5-2-4-3-0	32,6	43,7	298	298	226	391
31	30	0-6-1-5-2-4-3-0	32,6	43,7	298	298	226	391
32	31	0-6-1-5-2-4-3-0	32,6	43,7	298	298	226	391
33	32	0-6-1-5-2-4-3-0	32,6	43,7	298	298	226	391
34	33	0-6-1-5-2-4-3-0	32,6	43,7	298	298	226	391
35	34	0-6-1-5-2-4-3-0	32,6	43,7	298	298	226	391
36	35	0-6-1-5-2-4-3-0	32,6	43,7	298	298	226	391
37	36	0-6-1-5-2-4-3-0	32,6	43,7	298	298	226	391
38	37	0-6-1-5-2-4-3-0	32,6	43,7	298	298	226	391
39	38	0-6-1-5-2-4-3-0	32,6	43,7	298	298	226	391
40	39	0-2-1-6-5-4-3-0	33,8	42,5	298	298	226	391
41	2	0-6-1-4-2-5-3-0	40,5	53,8	298	298	326	391
42	4	0-6-1-3-2-4-5-0	41,7	45,5	298	298	326	391
43	7	0-5-1-6-4-2-3-0	43,9	55	298	298	326	391
44	10	0-5-1-6-3-2-4-0	40,2	33,2	298	298	326	391
45	1	0-1-6-5-2-4-3-0	45,2	55,5	298	298	326	391
46	9	0-5-1-6-2-4-3-0	31,4	42,7	298	298	326	391
47	5	0-2-1-5-6-4-3-0	33,1	44,8	298	298	326	391
48	3	0-4-1-5-2-6-3-0	35,7	45,9	298	298	326	391
49	11	0-6-1-5-2-4-3-0	32,6	43,7	298	298	326	391
50	13	0-6-1-5-2-4-3-0	35,4	45,5	298	298	326	391
51	14	0-6-2-5-1-4-3-0	36,2	49,8	298	298	326	391
52	12	0-6-4-5-2-1-3-0	38,4	51,2	298	298	326	391
53	6	0-6-3-5-2-1-4-0	37,3	50	298	298	326	391
54	8	0-6-1-2-5-4-3-0	33,8	42,5	298	298	326	391
55	15	0-6-1-4-2-5-3-0	40,5	53,8	298	298	326	391
56	4	0-6-1-3-2-4-5-0	41,7	45,5	298	298	326	391
57	7	0-5-1-6-4-2-3-0	43,9	55	298	298	326	391
58	10	0-5-1-6-3-2-4-0	40,2	33,2	298	298	326	391
59	1	0-1-6-5-2-4-3-0	45,2	55,5	298	298	326	391
60	4	0-4-1-5-2-3-4-0	42,0	54,6	298	298	326	391

The maximum capacity, trip distance, and minimum travel time were determined at the 28th iteration, based on calculations completed up to the 60th iteration. Maximum capacity in one month is 1451 boxes, minimum travel distance is 27.9 km, and minimum travel time is 35.2 minutes with route 0-6-5-1-2-3-4-0.

IV. CONCLUSION AND SUGGESTIONS

In connection with research regarding the use of the tabu search algorithm to solve the Capacitated Vehicle Routing Problem (CVRP) and optimize the distribution route for drug delivery in pharmacies, it was obtained that the maximum capacity that can be transported in one month is 1451 boxes, where every week the salesman brings it with a different capacity, week 1st week 298 boxes or 43 boxes of daily medicine, 2nd week 326 boxes or 47 boxes of daily medicine, 3rd week 391 boxes or 56 boxes of daily medicine, 4th week 436 boxes or 63 boxes of medicine sent per day, so the maximum capacity that sellers can carry every day is 63 boxes. From the results of calculating the minimum travel distance and minimum travel time, it was discovered that a minimum of 35.2 minutes and a minimum vehicle travel distance of 27.9 kilometers were required.

Suggestions for developing this research include implementing a tabu search algorithm for drug distribution across consumers within a single district, across districts, and across provinces. This research can also be further developed by implementing the tabu search algorithm in a computer program or software. Calculations using other algorithms, such as sweep algorithms, genetic algorithms, and ant algorithms.

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